Research Article

Effect of Rice and Wheat Straw and K-Silicate Application on Maize Growth

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Abstract | Maize is one of the valuable cereal crops consumed in Pakistan. Silicon (Si) ranked second in terms of abundance on earth surface and is very important for the growth of plants particularly under stress. Silicon is considered as quasiessential element for plant growth. The benefits of silicate fertilization are often correlated with the amount of silicon uptake by plants. In order to evaluate the growth and yield behavior of maize crop in response to different source of Si (straw and potassium silicate), a pot experiment was conducted at College of Agriculture, University of Sargodha, Pakistan in 2017. Different treatments including T_1= control, T_2= wheat straw (deficient @ 200 mg kg^{-1} of soil), T_3 = wheat straw (adequate @ 400 mg kg^{-1} of soil), T_4= rice straw (deficient @ 200 mg kg^{-1} of soil), T_5 =rice straw (adequate @ 400 mg kg^{-1} of soil), T_6 = K-silicate (deficient level @ 2 mg kg^{-1} of soil) and T_7 = K silicate (adequate @ 400 mg kg^{-1} of soil). All the pots were arranged according to completely randomized design (CRD). In each pot five hybrid maize seed (Monsanto 234) were sown but only 3 plants were maintained after germination. The fertilizers like nitrogen, phosphorus and potassium (Urea, SSP and SOP) were provided to the plants according to their requirement and time. The agronomic practices needed for plants were done according to plant demand. At maturity, data regarding yield components were recorded. Soil sampling was performed in all pots to analyze parameters of interest. Statistical analysis of collected data was done using Statistics 8.1 software. From the results it was concluded that by the using the both sources of silicon (straw and potassium silicate), plant growth and yield were improved but among these sources, potassium silicate was the best. Results showed that potassium silicate @ 200 mg kg^{-1} of soil gave higher values in almost all physiological and yield parameters.

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Introduction

Maize (*Zea mays* L.) is one of the valuable cereal crops consumed throughout the globe and likewise in Pakistan (Farhad *et al*., 2009). It is versatile plant in terms of adaptation to wide range of climatic conditions. Corn is another name of maize and it is grown throughout the world. Maize is agronomically very important because it is an important part of agro-industries all over the world. In world's GDP the contribution of agriculture is about 5.9%, while in Pakistan its contribution is about 21% (Chandio *et al*., 2016). In Pakistan, maize is cultivated over an area of about 0.939 million ha, while the production is 3.341 million tons (Gupta *et al*., 2014).

Fertilizers play an important role in up gradation of soil fertility and yield of crops (Ren *et al*., 2002). In the lithosphere the 2nd most abundant element is Si with share of 26% by weight (Snyder *et al*., 2007). The term beneficial is generally used for silicon, and silicon is mostly deposited on cell walls after up taken by the plants (Liang *et al*., 2005). A double layer of silicon is formed after accumulation in the leaves (Pereira *et al*., 2013), as a result the loss of water by maize is reduced as this accumulation resulted in transpiration reduction (Freitas *et al*., 2011). The silicon fertilizers are very important for agricultural products, as silicon play an important role in enhancing the abilities of crops to bear various stresses including resistant to insect and pests, mitigating the heavy metals toxicities, salt tolerance and resistance against freezing and drought conditions (Xiang *et al*., 2012; Marafon and Endres, 2013). Addition of silicon improved water use efficiency of maize because the silicon plummeted the rate of transpiration in leaves and flow of the water in to the xylem vessels (Gharineh and Karmollachaab, 2013).

Soil contains 1-45% Si (Sommer *et al*., 2006). Among various forms of silicon in soil, silicic acid $Si(OH)_4$ is the plant available form. The silicon is taken up by the plants, buildup in the stem, leaf and culm in the form of phytoliths or silicon bodies (Aoki *et al*., 2007). The complexes of silicon with iron, aluminum, and organic matter are the pedogenic forms of silicon (Farmer *et al*., 2005).

To supply the supplemental silica, potassium silicate's applications are mainly proposed. Considerable amounts of silica are present in most of the soils, but by continuously growing the crops that uptake large amounts of silica, the level of plant available silica can be reduced to such an extent that additional silicon fertilization is required. Consequently, the application of silicon amendments to the crops of tropical and temperate regions is necessary. Silicon fertilization is adopted in many countries of the world to achieve sustainability in crop production (Ma *et al*., 2001; Korndorfer and Lepsch, 2001). The source of highly soluble silicon and potassium is potassium silicate. In production systems of agriculture, it is used as silica amendment, but it also provides small amounts of potassium. Dry stalks of wheat and rice are referred as wheat straw and rice straw. These stalks remained behind after harvesting of grains. The important component of the cell wall of rice is silica and its concentration ranges from 5-15% and is dependent on the variety of rice so rice straw is good source of silicon (Blumberg, 2001).

Janislampi (2012) suggested the role of silicon application on growth and drought resistance of the maize and other cereal crops. By the application of silicon fertilizer to wheat and maize, an improvement in biomass at vegetative stage up to 17% and 18% respectively under water stress and saline conditions were recorded. The water use efficiency of maize is increased up to 36%. Rohanipoor *et al*. (2013) conducted an experiment to check the effects of silicon on some physiological properties of maize (*Zea mays* L.) under salt stress. Salinity can cause reduction in root and shoot dry weight, length of stem, chlorophyll content as well as relative water content of the maize plants while the application of silicon can improve all these parameters. Significant reduction was observed in treatments having EC less than 4 dSm^{-1}, whereas, the physiological properties of maize can be improved by improving the silicon availability. Therefore, in maize the resistance against salts can be improved by proper application of silicon. A pot study was designed in order to assess the role of Si nutrition on the maize crop's growth and to estimate the integrated impact of natural and artificial Si fertilizer sources on the growth of maize crop.

Materials and Methods

A pot experiment was conducted at research field of College of Agriculture, University of Sargodha. The current research was conducted during the year of 2017 to evaluate effect of silicate in straw and potassium-silicate on silicon cycling in aridisol on maize growth under control condition. Soil was filled in the pots after grinding and sieving @ 10 kg per pot. Various treatments were applied using CRD including T_1 = control, T_2 = wheat straw (deficient @ 200 mg kg^{-1} of soil), T_3 = wheat straw (adequate @ 400 mg kg^{-1} of soil), T_4= rice straw (deficient @ 200 mg kg^{-1} of soil), T_5 =rice straw (adequate @ 400 mg kg^{-1} of soil), T_6 = K-silicate (deficient level @ 2 mg kg^{-1} of soil) and T_7 = K silicate (adequate @ 400 mg kg^{-1} of soil). Hybrid maize seeds were sown in all the pots. Urea was added @ 160 kg ha^{-1} in two divided doses while sulphate of potash was added @ 60 kg ha^{-1}in single dose at sowing. Single super phosphate (SSP) @ 80 kg $ha^{-1}$was applied as a source of P. The agronomic practices needed for plants were done according to plant demand. Plants were harvested before R-stage (reproductive stage) after 40 days after germination. Plant height and stem diameter were recorded at maturity. Soil sampling was performed in all pots and samples were analyzed for desired parameters. Plants samples were oven dried at 72°C for constant weight. The collected data were subjected to statistics 8.1 software using analysis of variance (ANOVA) technique and Tukey's (HSD) test at 5% probability level was used for testing of means (Steel *et al*., 1997).

Results and Discussion

Plant height

Results (Figure 1) revealed that when the level of silicon becomes higher in soil solution accompanied by recommended chemical fertilizers. The plant height increased significantly. Addition of Si in any form resulted in plant height improvement. Statistical analysis showed that the difference among different treatment was significant. The minimum height of plant (108 cm) was observed in T_1 (control) containing no silicon. Among all the treatments, T_6 (K-silicate @ 200 mg kg^{-1} of soil) in combination with NPK was superior with respect to plant height as the plant height was maximum in this treatment i.e. 116cm. The results suggested that different sources and levels of Si significantly improved the plant height in maize. Abro *et al*. (2009) and Sharaf (2010) also reported that different Si sources (Silicic acid) improved the plant height in cereals including maize.

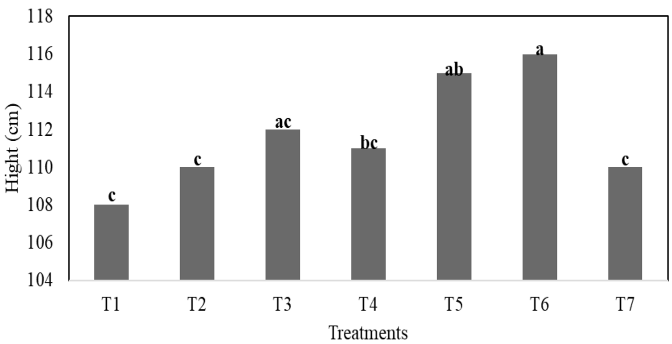

Figure 1: *Effect of straw and potassium- silicate on plant height of maize (cm).*

Stem diameter

The stem diameter is the vital agro-morphological character of crop plants and usually it represents the growth and resistance of the plants. Figure 2 revealed that all the treatments containing silicon improved the stem diameter in maize significantly over control (T_1). Data regarding stem diameter of maize showed that by the use of K-silicate T_6 (K-Silicate @ 200 mg kg^{-1} of soil) recoded maximum stem diameter (2.43 cm) of maize. On the other hand, the lowest level (1.92 cm) was recorded in T_1 (control) in which zero level of silicon was applied along with recommended NPK. These findings are similar with the results of earlier researchers (Abro *et al*., 2009; Suriyaprabha *et al*., 2012).

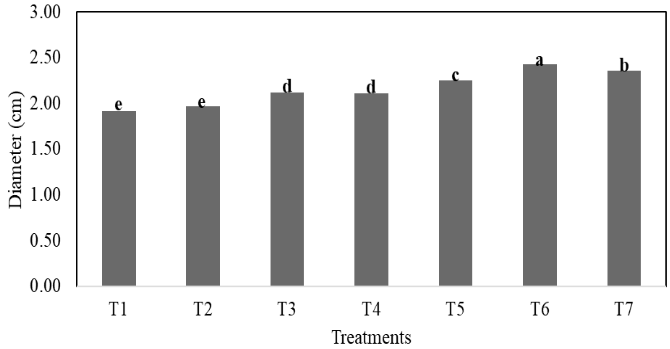

Figure 2: *Effect of straw and potassium- silicate on stem diameter of maize (cm).*

Si concentration in maize leaves sample (%)

All the treatments were significantly different when compared statistically (Figure 3). Maximum Si concentration (2.30 %) was observed in T_6 (K-silicate @ 200 mg kg^{-1} of soil). On the other hand, the lowest concentration (2.00%) was observed in T_1 (control treatment) having no Si. Results suggested that Si concentration in maize leaves was improved significantly by increasing level of Si, which reflected the impact of Si on growth of maize. These findings are related to the results of earlier researchers. Similar results were noted by Pilon *et al*. (2013) and Wang and Han (2007).

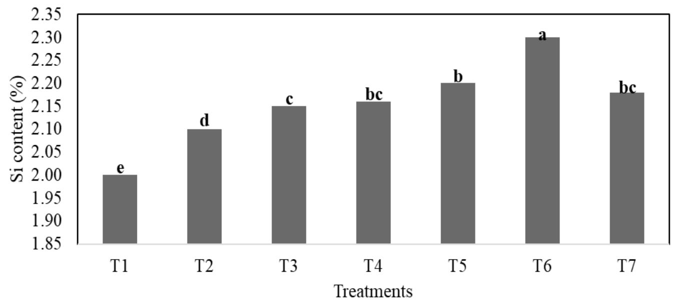

Figure 3: *Effect of straw and potassium- silicate on Si content in maize leaf (%).*

Si concentration in maize gains (µg g^{-1})

Data (Figure 4) revealed that in the grains of maize the level of silicon increased significantly in all treatments as compared to control in which no source of silicon was used and only NPK was applied. Two sources of Si were used i.e. straw and K-silicate. According to the results, maximum value (0.75 µg g^{-1}) was recorded in T6 (K-silicate @ 200 mg kg^{-1} of soil) and it was significant with other treatments when compared statistically. These findings were related to the results of Tahir *et al.* (2006).

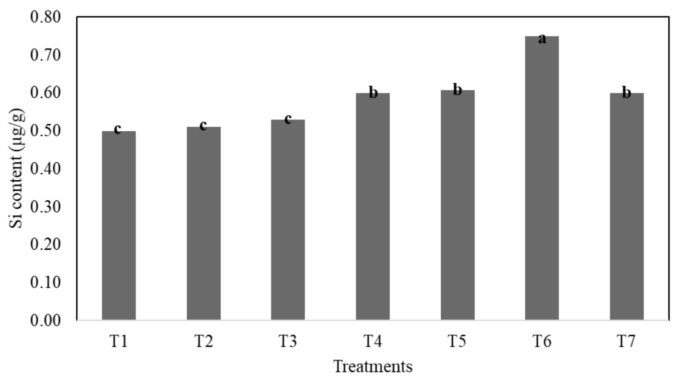

Figure 4: *Effect of straw and potassium- silicate on Si content in maize grain (µg/g).*

Si concentration in maize straw (%)

Results (Figure 5) revealed that in the straw of maize the level of silicon increased significantly in all treatments over control (T_1). The T6 (K-silicate @ 200 mg kg^{-1} of soil) was significant statistically with all other treatments and resulted in maximum concentration of silicon (2.00 %) in straw. On the other hand, the minimum concentration (1.70%) was seen in T_1 (control treatment) having 0 level of Si in addition to the recommended NPK. These results were similar with Mitani *et al.* (2005) who reported that the Si content in maize plant increased due to an increase of silicon in soil.

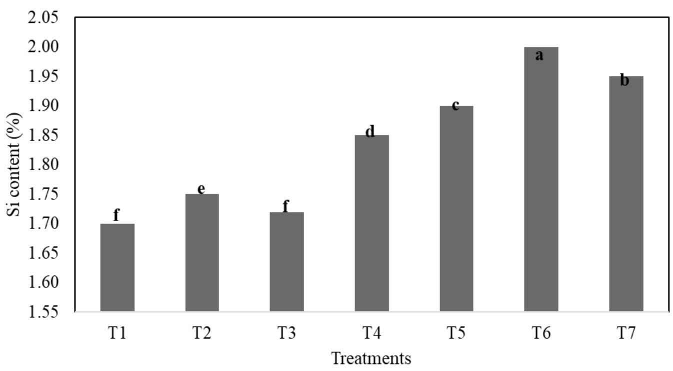

Figure 5: *Effect of straw and potassium- silicate on Si content in maize straw (%).*

Si concentration in plant roots (%)

Data (Figure 6) suggested that the level of silicon increased significantly in roots of maize in all treatments over control in which no silicon source was applied but only recommended NPK was applied. Results showed that maximum silicon concentration in roots was observed in T_6 (K-silicate @ 200 mg kg^{-1} of soil) and it proved statistically significant with all other treatments. It was suggested that Si content in maize root was significantly affected by increasing level of Si, which showed that the effect of Si on maize plant growth. Pilon *et al.* (2013) also reported similar findings.

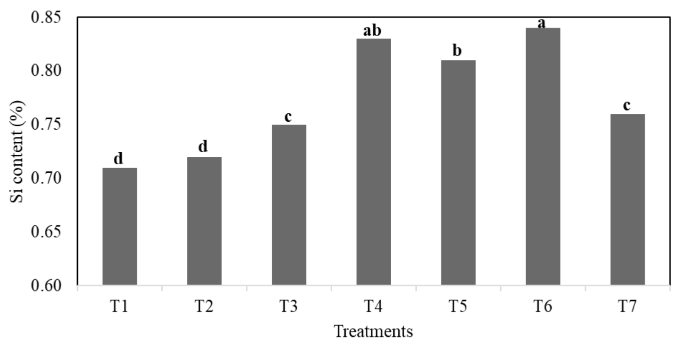

Figure 6: *Effect of straw and potassium- silicate on Si content in maize root (%).*

Available Si concentration in soil (ppm)

Results (Figure 7) revealed that available concentration of silicon in all treatments increased significantly as compared to control no silicon and recommended NPK. Results showed that the highest value (56.67 ppm) was noted in T_7 (K-silicate @ 400 mg kg^{-1} of soil) and it was significant with all other treatments when compared statistically. On the other hand, the lowest concentration (46.67 ppm) was seen in T_1 (control treatment) having 0 level of Si in addition to the recommended NPK. Similar, results were reported by Marxen *et al.* (2016). They revealed that available Si content in soil described the increasing behavior by the increasing the level of silicon.

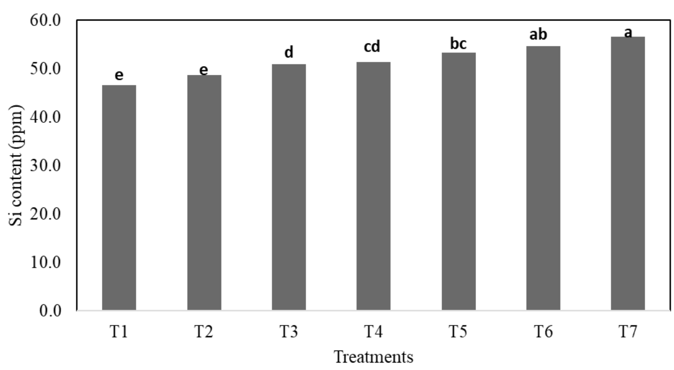

Figure 7: *Effect of straw and potassium- silicate on available Si content in soil (ppm).*

Available K in soil

Data regarding available potassium contents in soil was presented in Figure 8 which showed that by using K-silicate T_7 (K-silicate @ 400 mg kg^{-1} of soil), maximum available potassium contents (260 ppm) were noted in soil. Finding of previous scientists are also in the same direction. Tahir *et al.* (2006)

also noted increase in soil available K content with increasing the level of potassium silicate.

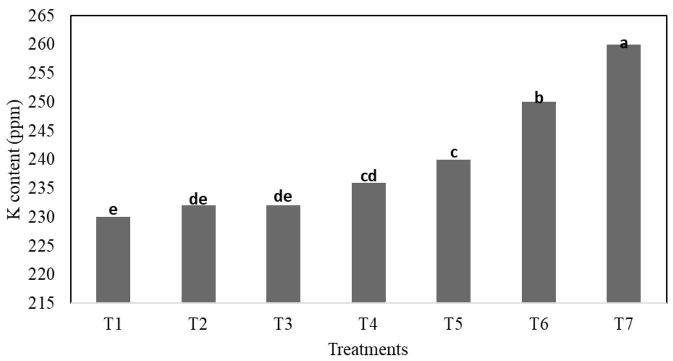

Figure 8: *Effect of straw and potassium- silicate on available K content in soil (ppm).*

Conclusions and Recommendations

It was concluded that straw and potassium silicate impart significant impact on growth, yield and nutrients concentration in maize plant as well as on soil properties. Among all the treatments, the use of potassium silicate was proved to be the best to obtain the highest growth, yield and nutrients concentration in plants. By increasing the silicon level, growth and nutrients concentration increased in maize plant. K-silicate showed more effective results than straw sources. However, both Si sources improved the maize growth significantly as compared to control.

Novelty Statement

Role of silicon as an essential nutrient is under process so this research will contribute to establish its essentiality for the growth of maize.

Author's Contributions

Amir Aziz: Conception and design of research work, conduction of experiment and write up.
Mukkram Ali Tahir: Academic supervisor and guided throughout the research tenure.
Noor-us-Sabah: Interpretation of data and proof reading.
Ghulam Sarwar: Co-supervision, interpretation of data and proof reading.
Sher Muhammad: Contributed in statistical analysis.

Conflict of interest
The authors have declared no conflict of interest.

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